

**METHOD AND APPARATUS FOR DYNAMIC VOICE RESERVATION WITHIN  
WIRELESS NETWORKS**

1

**BACKGROUND OF THE INVENTION**

2 **1. Technical Field**

3 The present invention pertains to wireless networks employing voice reservation  
4 protocols. In particular, the present invention pertains to multi-hop wireless Ad-Hoc  
5 networks employing voice reservation with dynamic selection of frame architectures  
6 depending on voice mode operation (e.g., simplex/duplex) and associated  
7 retransmission/acknowledgement mechanisms.

8

9 **2. Discussion of the Related Art**

10 Wireless Ad-Hoc networks may transfer information in the form of voice and data.  
11 However, transfer of voice information within such networks has more stringent  
12 requirements relative to those for data transfer since voice information is transferred as a  
13 continuous stream of packets with each packet representing a frame of voice data that has  
14 to be received in correct time order. If a frame is received late, the frame is considered  
15 lost. In a tactical environment, an acceptable delay is typically required to be on the order  
16 of 50 ms/hop (e.g., milliseconds per hop) with a completion rate in the approximate range  
17 of 95% to 99%.

18 Time Division Multiple Access (TDMA) is a scheme that allows plural users to  
19 share the same communication media. The TDMA frame may be utilized for integration  
20 of voice and data, where the TDMA frame is divided between voice and data, while still  
21 sharing the same channel. Basically, each TDMA frame is partitioned into a quantity of  
22 time slots within which information (e.g., voice and/or data) may be transferred over the  
23 communication media between network sites. Plural users may reserve (or be assigned)  
24 different time slots within the TDMA frame to perform communications over the same  
25 communication media. The use of a TDMA architecture and a conventional Packet  
26 Reservation Multiple Access (PRMA) scheme was first proposed for voice  
27 communication between a base station and a mobile user. However, PRMA may further  
28 be applied for home networking technologies.

1        The key feature of PRMA is that a time slot is reserved by a user through an uplink  
2 and is later confirmed by the base station through a down link. However, users have to  
3 contend for any unused time slots in order to get a reservation. The original PRMA  
4 scheme allows plural users to contend for time slot reservation and suffer the consequence  
5 of collisions (e.g., plural transmissions on the same time slots for reservations). The  
6 PRMA scheme was later refined by inserting dedicated reservation time slots in the  
7 TDMA frame. Plural users utilize these dedicated time slots by using conventional  
8 protocols (e.g., ALOHA, CSMA, etc.) to make time slot reservations.

9        In the original PRMA scheme, a user intending to send voice information uses an  
10 available time slot to inform the base station of a reservation. In a tactical environment,  
11 the base station does not exist. Therefore, the reservation must be set up through a  
12 signaling protocol. One conventional signaling protocol is RSVP which conveys the  
13 application resource requirements to the network. The reservation in this protocol is  
14 receiver oriented. Typically, the source network site or sender transmits a path message  
15 down stream to the receiver which returns a reservation request (RESV) message up  
16 stream to the sender. The RESV message travels hop by hop from the receiver to the  
17 source. The resources are allocated in response to intermediate routers determining  
18 availability of sufficient resources to satisfy the request.

19       The related art described above suffers from several disadvantages. In particular,  
20 the techniques described above concern either cellular networks or home networks. The  
21 cellular network is a one-hop network (e.g., between the base station and the mobile user),  
22 while the home network consists of a down-link and up-link similar to the cellular network  
23 infrastructure. Thus, these techniques are limited to specific types of networks and do not  
24 address the environments of Ad-Hoc multi-hop networks. With respect to multi-hop  
25 packet radio networks, there are protocols dealing with a distributed time-slot assignment.  
26 However, this application is primarily limited to data transfer. Although the enhanced  
27 PRMA scheme employs dedicated time slots for reservations, the resources available in  
28 the TDMA frame for voice information are reduced, while controlling the number of time  
29 slots required for a successful time slot reservation is difficult and complex.

30       Basically, if time slots can be successfully reserved, collision-free voice  
31 communication can be maintained. However, the techniques described above generally do  
32 not address the issue of packet loss due to external interference. In a tactical environment,  
33 interference could be due to unfriendly jamming. Although spread spectrum technology

1 can provide some resistance, packet loss may still occur depending on the number and  
2 strength of the interference sources.

3 In a home environment, interference may originate from a microwave oven.  
4 Although the conventional HomeRF architecture addresses packet loss due to external  
5 interference, this architecture is simplified and limited due to the one-hop nature of the  
6 home network.

7 In addition, the RSVP protocol is receiver oriented, where the reservation is made  
8 only on the reverse path. Further, with respect to TDMA slot reservation, each network  
9 node cannot independently make slot reservations since the slot reservation of one node  
10 depends upon the reservation of the previous nodes.

11

## 12 **OBJECTS AND SUMMARY OF THE INVENTION**

13 Accordingly, it is an object of the present invention to employ a voice reservation  
14 protocol within multi-hop wireless Ad-Hoc networks that supports voice and data  
15 communication and incorporates retransmission and acknowledgement mechanisms.

16 It is another object of the present invention to employ a voice reservation protocol  
17 within multi-hop wireless Ad-Hoc networks that dynamically selects a TDMA frame  
18 architecture depending on voice mode operation (e.g., simplex/duplex) and associated  
19 retransmission/acknowledgement mechanisms.

20 Yet another object of the present invention is to employ a source-oriented  
21 reservation scheme within mulit-hop wireless Ad-Hoc networks, where each intermediate  
22 network node along the propagation path determines the manner to accomplish slot  
23 reservation based upon embedded reservation information within data packets.

24 Still another object of the present invention is to employ a voice reservation  
25 protocol within multi-hop wireless Ad-Hoc networks that is capable of using separate  
26 dedicated channels or a single channel for voice and data.

27 A further object of the present invention is to employ a voice reservation protocol  
28 within multi-hop wireless Ad-Hoc networks that supports voice/data load balancing over  
29 different channels.

30 Yet another object of the present invention is to employ a voice reservation  
31 protocol within multi-hop wireless Ad-Hoc networks that utilizes speech silence and  
32 increased communication reliability to enhance performance.

1        The aforesaid objects may be achieved individually and/or in combination, and it is  
2 not intended that the present invention be construed as requiring two or more of the  
3 objects to be combined unless expressly required by the claims attached hereto.

4        According to the present invention, a multi-hop wireless Ad-Hoc network employs  
5 a voice reservation protocol. The protocol supports voice and data communication and  
6 incorporates retransmission and acknowledgement (ACK) mechanisms. A TDMA frame  
7 architecture is dynamically selected depending on voice mode operation (e.g.,  
8 simplex/duplex) and associated retransmission/acknowledgement mechanisms. A source-  
9 oriented reservation procedure is utilized, where a source node transmits a reservation  
10 packet that embeds TDMA frame architecture and other information. The packet is  
11 transmitted to a destination node and is further piggybacked on existing neighbor  
12 discovery packets to reduce network and protocol overhead. Each intermediate network  
13 node along the propagation path determines the manner in which to accomplish slot  
14 reservation based on the embedded information in the reservation packet. The protocol  
15 may use separate dedicated channels or a single channel for voice and data, and supports  
16 voice/data load balancing over different channels. In addition, the protocol may utilize  
17 speech silence and increased communication reliability to enhance performance.

18       The present invention provides several advantages. In particular, the present  
19 invention applies to multi-hop wireless Ad-Hoc networks. Since jamming and other  
20 interference are common in tactical environments employing wireless Ad-Hoc networks,  
21 retransmissions and acknowledgement (ACK) mechanisms are included in the TDMA  
22 frame structure. Various different TDMA frame architectures are provided depending  
23 upon the protection and the quality of voice information. The selection of an architecture  
24 is performed dynamically on the basis of resource availability. The voice traffic and  
25 resource reservation slots can be on the same channel or, preferably, on different channels.  
26 In this case, the resource reservation process can use the data access schemes in the data  
27 channel to accomplish the reservation task. Since the present invention may employ a  
28 different frequency channel for voice information, the number of time slots used for  
29 reservation in the data channel has no impact on the resources available for voice traffic.  
30 In other words, more voice circuits can be supported since reservation is performed on a  
31 different channel.

32       Although the voice and data traffic can share the same channel within the present  
33 invention, the preferred manner is to utilize different channels. This manner obviates

1 adverse effects of heavy data traffic and large message size that may require excessive  
2 resources and simplifies voice time slot management while removing dependence upon  
3 data time slot utilization. In other words, resource management is simplified since voice  
4 channels are not competing for data time slots. However, when traffic is light, the use of  
5 separate channels may bring inefficiencies that waste resources either in the data channel  
6 or in the voice channel. In order to compensate for these inefficiencies, the present  
7 invention employs a dynamic scheme to apply voice traffic to the data channel and data  
8 traffic to the voice channel.

9 Moreover, the present invention employs a source oriented signaling protocol (as  
10 opposed to the receiver oriented RSVP protocol described above). The reservation starts  
11 on the forward path between source and destination nodes, while the reservation  
12 confirmation is performed on the return or reverse path. This forward reservation  
13 approach enables neighbors to be informed of the reservation immediately and enhances  
14 maintenance of correct slot time sequence. A reservation packet sent by the source node  
15 embeds information about the integrated path, slot number and the selected frame  
16 architecture, wherein each intermediate node determines the manner in which to  
17 accomplish the slot reservation based upon the embedded information.

18 In addition, the voice reservation protocol employed by the present invention may  
19 operate in a full-duplex mode, while a voice detector may be employed to detect voice  
20 activity and filter out unwanted silence intervals, thereby conserving bandwidth.

21 The above and still further objects, features and advantages of the present  
22 invention will become apparent upon consideration of the following detailed description of  
23 specific embodiments thereof, particularly when taken in conjunction with the  
24 accompanying drawings wherein like reference numerals in the various figures are utilized  
25 to designate like components.

26

#### 27 BRIEF DESCRIPTION OF THE DRAWINGS

28 Fig. 1A is a diagrammatic illustration of network nodes according to the present  
29 invention arranged in an exemplary communication network.

30 Fig. 1B is a block diagram of a network node of Fig. 1A.

31 Fig. 2 is a diagrammatic illustration of an exemplary TDMA frame architecture  
32 supporting duplex voice communications (e.g., simultaneous voice communications  
33 between sender and receiver) and retransmissions.

1       Fig. 3 is a diagrammatic illustration of an exemplary TDMA frame architecture  
2 supporting simplex voice communications (e.g., sender and receiver communicate one at a  
3 time) and retransmissions.

4       Fig. 4 is a diagrammatic illustration of an exemplary TDMA frame architecture  
5 supporting duplex voice communications (e.g., simultaneous voice communications  
6 between sender and receiver) without retransmissions.

7       Fig. 5 is a diagrammatic illustration of an exemplary TDMA frame architecture  
8 supporting simplex voice communications (e.g., sender and receiver communicate one at a  
9 time) without retransmissions.

10      Fig. 6 is an exemplary procedural flow chart illustrating the manner in which a  
11 network node requests reservation of communication links for transfer of voice  
12 information according to the present invention.

13      Figs. 7A - 7B are an exemplary procedural flowchart illustrating the manner in  
14 which a network node processes the reservation request according to the present invention.

15      Fig. 8 is an exemplary flow chart illustrating the manner in which a network node  
16 transfers voice information over the reserved communication links according to the  
17 present invention.

18      Fig. 9 is an exemplary flow chart illustrating the manner in which a network node  
19 conserves bandwidth by removing silence frames from voice transmissions according to  
20 the present invention.

21      Fig. 10 is an exemplary flow chart illustrating the manner in which a network node  
22 allocates transmissions over voice and data channels according to the present invention.

23      Fig. 11 is a diagrammatic illustration of an exemplary voice channel frame  
24 architecture with integrated voice information and data and supporting retransmissions.

25      Fig. 12 is a diagrammatic illustration of an exemplary voice channel frame  
26 architecture with integrated voice information and data without retransmissions.

27      Fig. 13 is a diagrammatic illustration of an exemplary data channel frame  
28 architecture with integrated voice information and data and supporting retransmissions.

29      Fig. 14 is a diagrammatic illustration of an exemplary data channel frame  
30 architecture with integrated voice information and data without retransmissions.

31

32      **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

1        An exemplary network architecture that may be employed by the present invention  
2 is a multi-hop wireless Ad-Hoc network. This type of network does not include an  
3 infrastructure (e.g., there is no base station as in a cellular network, where a single-hop  
4 environment of a cellular network becomes a special case) and may be utilized in a hostile  
5 network environment (e.g., a tactical battlefield, etc.) with unfriendly jamming. An  
6 exemplary wireless Ad-Hoc network including network nodes according to the present  
7 invention is illustrated in Fig. 1A. Specifically, wireless network 300 includes a plurality  
8 of nodes 14 arranged in islands 18. Each island is in the form of a flat multi-hop network  
9 and includes corresponding island member nodes 14 (e.g., with an approximate maximum  
10 of fifty nodes) with one of those member nodes designated as an island head node 15.  
11 These island arrangements form a first tier of network 300 and facilitate communication  
12 within an island between the island head and member nodes and between the member  
13 nodes themselves. The head nodes of each island are in communication with each other  
14 and form a backbone network 16. The backbone network essentially forms a second tier  
15 of network 300 and facilitates communications between nodes of different islands (e.g.,  
16 generally providing communications over greater distances). For example, a node A from  
17 a first island desires to transmit a message to node B of a second island. Node A transmits  
18 the message to a corresponding head node C of the first island that utilizes the second tier  
19 of network 300 to forward the message to a head node D of the second island. Head node  
20 D subsequently forwards the received message to destination node B. Alternatively, nodes  
21 14 may be arranged to form a network including a single or any quantity of tiers.

22        A network node 14 according to the present invention is illustrated in Fig. 1B. In  
23 general, each radio or node 14 within network 300 has a voice channel including a Time  
24 Division Multiple Access (TDMA) frame architecture. Preferably, node 14 includes at  
25 least two frequency channels, wherein one channel is utilized for voice information and  
26 another channel is utilized for data. Specifically, node 14 includes a voice transceiver 22,  
27 a data transceiver 24, a processor 26 and audio devices 28. The processor is preferably  
28 implemented by a conventional microprocessor or controller and controls the node to  
29 transmit and receive messages in accordance with the routing and communication  
30 protocols described below. Voice transceiver 22 is preferably implemented by a  
31 conventional transceiver (e.g., transmitter and receiver) that transmits and receives  
32 messages, preferably in the form of radio frequency (RF) signals, over a voice channel in  
33 accordance with processor instructions. Similarly, data transceiver 24 is preferably

1 implemented by a conventional transceiver (e.g., transmitter and receiver) that transmits  
2 and receives messages, preferably in the form of radio frequency (RF) signals, over a data  
3 channel in accordance with processor instructions. Audio devices 28 preferably include  
4 various conventional audio devices (e.g., microphone, speaker, etc.) and optional circuitry  
5 (e.g., to process and perform conversions of voice signals between digital and analog  
6 domains, etc.) to transfer audio signals between the node and a user. The audio devices  
7 are typically coupled to processor 26 for control and transfer of information to facilitate  
8 transmission and reception of voice signals. The node further includes an identifier (e.g., a  
9 code or identification number) to identify the particular node and a database (not shown)  
10 to store information pertaining to neighboring nodes to facilitate reservations and/or  
11 routing as described below. A head node 15 is substantially similar to node 14 described  
12 above. Voice reservation may utilize the data channel and employ any suitable data  
13 channel access schemes (e.g., CSMA, HAMA or any other collision free protocols).

14 The network preferably employs a link-state type of routing protocol. The  
15 database of each node 14 (e.g., island head and member nodes) maintains information  
16 enabling that node to determine appropriate paths for routing messages through the  
17 network. The information typically relates to links between the various network nodes.  
18 The node databases are synchronized in accordance with the routing protocol by  
19 transference of database update packets or messages between nodes that provide network  
20 connectivity information. In addition, each node (e.g., island head and member nodes)  
21 periodically broadcasts a beacon type or neighbor discovery packet. This packet basically  
22 advertises the presence of a node within the network and is typically utilized by nodes for  
23 "keep alive" and neighbor discovery purposes.

24 In order to facilitate wireless communications, the present invention employs Time  
25 Division Multiple Access (TDMA) frame schemes or architectures. Network nodes  
26 dynamically select an appropriate TDMA frame architecture to utilize for a  
27 communication. The TDMA schemes preferably include four frame architectures that are  
28 based upon support for retransmissions during voice traffic and simultaneous voice  
29 transmissions between sender and receiver (e.g., full duplex or simplex). When a  
30 reservation is successfully accomplished, there is normally no voice packet loss in an  
31 interference-free environment. Since packet loss may occur in the presence of  
32 interference, the TDMA frame structures include a retransmission mechanism. The frame  
33 architectures basically include the various combinations of the retransmission and

1 simultaneous voice transmission features (e.g., duplex/retransmission,  
2 simplex/retransmission, duplex/no retransmissions and simplex/no retransmissions) as  
3 described below.

4 Initially and by way of example only, the types of TDMA frame architectures  
5 employed by the present invention are described with respect to an exemplary network  
6 including two hops between a node A and a node C, where each TDMA frame includes N  
7 time slots and every frame of voice information can be sent out within one time slot.  
8 Thus, a forward communication path may be from node A to an intermediate or router  
9 node B (e.g., first hop), and from node B to node C (e.g., second hop). However, the  
10 TDMA frame architectures may vary to accommodate any network configurations  
11 employed by the present invention.

12 An exemplary type of TDMA frame architecture employed by the present  
13 invention for network communications supporting full duplex communications and  
14 retransmissions is illustrated in Fig. 2. Specifically, TDMA frame architecture 20 includes  
15 transmission slots (e.g., slots 1 - 6 with acknowledgement (ACK) slots 3 and 6) and  
16 retransmission slots (e.g., slots 9 – 12). In a forward (FWD) communication path (e.g.,  
17 from node A to node C), node A generates voice packets that are forwarded by node B to  
18 node C. For example, node A may reserve transmission slot 1 and retransmission slot 9  
19 (e.g., each associated with label ‘A (FWD)’ in Fig. 2), router node B may reserve  
20 transmission slot 2 and retransmission slot 10 (e.g., each associated with label ‘B (FWD)’  
21 in Fig. 2) and node C may reserve ACK slot 3 (e.g., associated with label ‘C ACK (FWD)’  
22 in Fig. 2). Thus, slot 1 is utilized for communications from node A to node B (e.g., by  
23 node A for transmissions and by node B to receive transmissions from node A), while slot  
24 2 is utilized for communications from node B to node C. Slot 3 is utilized by node C for  
25 explicit acknowledgements (ACK).

26 The example shows that the retransmission slots for a frame architecture start at  
27 time slot  $N/2+1$  when  $N$  is set to sixteen. If node A reserves slot S, the retransmission slot  
28 may start at a slot number greater than  $S+P$ , where P is the estimated maximum number of  
29 hops. The number of required slots in a frame may be estimated as follows:

30  
31

1      
$$N = \frac{R_c T_f}{R_s T_f + E + \beta} \quad (\text{Equation 1})$$

2  
3      where  $R_c$  represents the channel rate,  $R_s$  represents the voice coding rate,  $E$  represents the  
4      protocol overhead,  $\beta$  is a safety margin and  $T_f$  represents the frame period. The slot size  
5      or time interval of each slot may be expressed as  $T_f/N$ . The slot size is large enough to  
6      allow the transmission of voice packets.

7      In a return (RTN) communication path (e.g., from node C to node A), node C  
8      generates voice packets that are relayed by node B to node A. By way of example only,  
9      node C may reserve transmission slot 4 and retransmission slot 11 (e.g., each associated  
10     with the label 'C (RTN)' in Fig. 2). Node B may reserve transmission slot 5 and  
11     retransmission slot 12 (e.g., each associated with the label 'B (RTN)' in Fig. 2), while  
12     node A may reserve acknowledgement (ACK) slot 6 (e.g., associated with the label 'A  
13     ACK (RTN)' in Fig. 2). Thus, architecture 20 includes voice information for both the  
14     forward and return communication paths to support full duplex communications and  
15     provides slots for retransmission of voice information.

16      The transmissions from intermediate or router node B are considered as implicit  
17     acknowledgements (ACK), thereby obviating the need for explicit ACK slots. For  
18     example, node A can hear or receive the voice packets sent from node B to node C,  
19     thereby informing node A that the transmitted voice packets have been received by node  
20     B. If node A does not hear or receive such transmission after occurrence of one voice slot,  
21     node A considers the transmitted voice packet to be lost and retransmits that packet via  
22     retransmission slot 9. Since node C does not relay the received voice packet, node C  
23     needs to send an explicit acknowledgement (ACK) in order to inform node B that a  
24     transmitted voice packet has been received. If node B does not hear or receive an explicit  
25     ACK after the occurrence of one time slot, node B considers the transmitted voice packet  
26     to be lost and retransmits that packet using retransmission slot 10.

27      Once several frames have passed through the forward communication path, node C  
28     starts sending voice bursts to node A on the return communications path using  
29     transmission slot 4. If node C does not hear or receive the transmissions from node B to  
30     node A using transmission slot 5 (e.g., an implicit acknowledgement as described above),  
31     node C considers the transmitted voice packet to be lost and retransmits that packet using  
32     retransmission slot 11. Since node A is the destination for the return path and does not  
33     relay the received voice packet, node A needs to send an explicit acknowledgement

1 (ACK) in order to inform node B that a transmitted voice packet has been received. If  
2 node B does not hear or receive an explicit ACK from node A using slot 6, node B  
3 retransmits that packet using retransmission slot 12. The number of slots required for  
4 communication in this type of TDMA architecture is  $4H+2$ , where H is the total number of  
5 hops.

6 An exemplary type of TDMA frame architecture employed by the present  
7 invention for network communications supporting simplex communications and  
8 retransmissions is illustrated in Fig. 3. Specifically, TDMA frame architecture 30 includes  
9 transmission slots (e.g., slots 1 - 3 with acknowledgement (ACK) slot 3) and  
10 retransmission slots (e.g., slots 9 – 10). In a forward (FWD) communication path (e.g.,  
11 from node A to node C), node A generates voice packets that are forwarded by node B to  
12 node C. By way of example only, node A may reserve transmission slot 1 and  
13 retransmission slot 9 (e.g., each associated with label ‘A (FWD)’ in Fig. 3), router node B  
14 may reserve transmission slot 2 and retransmission slot 10 (e.g., each associated with label  
15 ‘B (FWD)’ in Fig. 3) and node C may reserve ACK slot 3 (e.g., associated with label ‘C  
16 ACK (FWD)’ in Fig. 3). Thus, slot 1 is utilized for communications from node A to node  
17 B (e.g., by node A for transmissions and by node B to receive transmissions from node A),  
18 while slot 2 is utilized for communications from node B to node C. Slot 3 is utilized by  
19 node C for explicit acknowledgements (ACK).

20 Since architecture 30 supports simplex communications, a return communication  
21 path (e.g., from node C to node A) similarly utilizes slots 1, 2 and 3 for transmission and  
22 slots 9 and 10 for retransmissions, where node C generates voice packets that are relayed  
23 by node B to node A. By way of example only, node C may utilize transmission slot 1 and  
24 retransmission slot 9 (e.g., each associated with the label ‘C (RTN)’ in Fig. 3). Node B  
25 may utilize transmission slot 2 and retransmission slot 10 (e.g., each associated with the  
26 label ‘B (RTN)’ in Fig. 3), while node A may utilize acknowledgement (ACK) slot 3 (e.g.,  
27 associated with the label ‘A ACK (RTN)’ in Fig. 3). Once node A finishes talking or  
28 transmitting voice packets, node A becomes silent and waits for a response (e.g., voice  
29 packets) from node C. Node C may use the same slots node A utilized. This arrangement  
30 is reasonable since both the sender and receiver presumably do not speak or transmit voice  
31 packets at the same time. Thus, although the forward and return communication paths  
32 share the same time slots, collisions do not occur.

1        The transmissions from intermediate or router node B are considered as implicit  
2 acknowledgements (ACK), thereby obviating the need for explicit ACK slots as described  
3 above. For example, node A can hear or receive the voice packets sent from node B to  
4 node C, thereby informing node A that the transmitted voice packets have been received  
5 by node B. If node A does not hear or receive such transmission after occurrence of one  
6 voice slot, node A considers the transmitted voice packet to be lost and retransmits that  
7 packet via retransmission slot 9. Since node C does not relay the received voice packet,  
8 node C needs to send an explicit acknowledgement (ACK) in order to inform node B that  
9 a transmitted voice packet has been received. If node B does not hear or receive an  
10 explicit ACK after the occurrence of one time slot, node B considers the transmitted voice  
11 packet to be lost and retransmits that packet using retransmission slot 10.

12       Once several frames have passed through the forward communication path, node C  
13 starts sending voice bursts to node A on the return communications path using  
14 transmission slot 1. If node C does not hear or receive the transmissions from node B to  
15 node A using transmission slot 2 (e.g., an implicit acknowledgement as described above),  
16 node C considers the transmitted voice packet to be lost and retransmits that packet using  
17 retransmission slot 9. Since node A is the destination for the return path and does not  
18 relay the received voice packet, node A needs to send an explicit acknowledgement  
19 (ACK) in order to inform node B that a transmitted voice packet has been received. If  
20 node B does not hear or receive an explicit ACK from node A using slot 3, node B  
21 retransmits that packet using retransmission slot 10. The number of slots required for  
22 communication in this type of TDMA frame architecture is  $2H+1$ , where H is the total  
23 number of hops.

24       An exemplary TDMA frame architecture employed by the present invention for  
25 network communications supporting full duplex communications without retransmissions  
26 is illustrated in Fig. 4. Specifically, TDMA frame architecture 40 includes transmission  
27 slots (e.g., slots 1 – 4, without retransmission and acknowledgement (ACK) slots). In a  
28 forward (FWD) communication path (e.g., from node A to node C), node A generates  
29 voice packets that are forwarded by node B to node C. By way of example only, node A  
30 may reserve transmission slot 1 (e.g., associated with label ‘A (FWD)’ in Fig. 4), while  
31 router node B may reserve transmission slot 2 (e.g., associated with label ‘B (FWD)’ in  
32 Fig. 4). Thus, slot 1 is utilized for communications from node A to node B (e.g., by node

1 A for transmissions and by node B to receive transmissions from node A), while slot 2 is  
2 utilized for communications from node B to node C.

3 In a return (RTN) communication path (e.g., from node C to node A), node C  
4 generates voice packets that are relayed by node B to node A. By way of example only,  
5 node C may reserve transmission slot 3 (e.g., associated with the label ‘C (RTN)’ in Fig.  
6 4), while node B may reserve transmission slot 4 (e.g., associated with the label ‘B (RTN)’  
7 in Fig. 4). Thus, architecture 40 includes voice information for both the forward and  
8 return communication paths to support full duplex communications. The number of slots  
9 required for communication in this type of TDMA architecture is  $2H$ , where  $H$  is the total  
10 number of hops.

11 An exemplary TDMA frame architecture employed by the present invention for  
12 network communications supporting simplex communications without retransmissions is  
13 illustrated in Fig. 5. Specifically, TDMA frame architecture 50 includes transmission slots  
14 (e.g., slots 1 – 2, without retransmission and acknowledgement (ACK) slots). In a forward  
15 (FWD) communication path (e.g., from node A to node C), node A generates voice  
16 packets that are forwarded by node B to node C. By way of example only, node A may  
17 reserve transmission slot 1 (e.g., associated with label ‘A (FWD)’ in Fig. 5), while router  
18 node B may reserve transmission slot 2 (e.g., associated with label ‘B (FWD)’ in Fig. 5).  
19 Thus, slot 1 is utilized for communications from node A to node B (e.g., by node A for  
20 transmissions and by node B to receive transmissions from node A), while slot 2 is utilized  
21 for communications from node B to node C.

22 Since architecture 50 supports simplex communications, a return communication  
23 path (e.g., from node C to node A) similarly utilizes slots 1 and 2 for transmission. By  
24 way of example only, node C may utilize transmission slot 1 (e.g., associated with the  
25 label ‘C (RTN)’ in Fig. 5), while node B may utilize transmission slot 2 (e.g., associated  
26 with the label ‘B (RTN)’ in Fig. 5). Once node A finishes talking or transmitting voice  
27 packets, node A becomes silent and waits for a response (e.g., voice packets) from node C.  
28 Node C may use the same slots utilized by node A as described above. The number of  
29 slots required for communication in this type of TDMA architecture is  $H$ , where  $H$  is the  
30 total number of hops.

31 The TDMA frame architectures of the present invention support retransmissions as  
32 described above. If different frequency channels are used for transmissions and  
33 retransmissions, the probability of a successful communication is enhanced for

1 retransmissions. Accordingly, the present invention may assign retransmission slots to  
2 another frequency channel to achieve the enhanced probability of success. In particular, a  
3 network node transmits voice packets at the assigned or reserved time slots for  
4 transmissions. When a retransmission is required, the same voice packet is transmitted  
5 using retransmission slots over a different frequency channel. In order to simplify  
6 switching channels, the transmission slots are assigned or reserved on the first half of a  
7 frame, while the retransmission slots are assigned on the second half of the frame. The  
8 channel in this approach is switched based on transmission and retransmission slots.

9 Network nodes of the present invention basically perform reservation request,  
10 reservation confirmation, voice communication and voice termination in order to facilitate  
11 communications within the network as described below. A network node according to the  
12 present invention establishes communication links to commence voice communication by  
13 requesting a reservation via a reservation packet as illustrated in Fig. 6. Specifically, a  
14 network node 14 (Fig. 1A) initiating communications with another network node  
15 generates a reservation packet at step 60. Each reservation packet includes sequence of  
16 routing path aggregate, slot assignment aggregate, frame architecture assignment  
17 aggregate, available resources, source address and next hop address. The routing path  
18 aggregate is a sequence of nodes the voice packets traverse to a destination node, while the  
19 slot assignment aggregate is the sequence of slot assignments this sequence of routing  
20 reserves.

21 The frame architecture assignment aggregate refers the TDMA frame architecture  
22 employed. The node selects the TDMA architecture based upon two configuration  
23 parameters, typically entered by a user. One parameter specifies the mode (e.g., full  
24 duplex or simplex) and the other parameter specifies a retransmission flag indicating  
25 support for retransmissions. The combination of the mode and retransmission flag yields a  
26 configuration number (e.g., a two bit parameter (e.g., with one bit specifying simplex or  
27 duplex mode and the other bit representing the retransmission flag), where each parameter  
28 value corresponds to a particular TDMA architecture). The node further determines from  
29 node resources the particular configuration number (e.g., TDMA architecture) the node  
30 may support. If the supportable configuration number is different from the desired  
31 configuration (e.g., entered by a user), the supportable configuration number has  
32 precedence.

1        The generated packet is transmitted by the node at step 62, preferably over the data  
2 channel. The reservation packet basically travels from the initiating node to the  
3 destination node hop by hop using a routing path supplied from a routing module (e.g.,  
4 within the node processor) that analyzes routing information within a node database to  
5 determine an appropriate communication path.

6        Once the node has made a reservation (e.g., the reservation has been confirmed as  
7 described below) at step 64, reservation information (e.g., slot, architecture, the number of  
8 empty slots, etc.) is transmitted to neighboring nodes over the data channel at step 68. In  
9 order to limit additional overhead to the network, the reservation information is placed  
10 within beacon or neighbor discovery packets that are transmitted periodically to discover  
11 neighboring nodes. This obviates the need for a broadcast packet to send the reservation  
12 information and provides each node with reservation information of neighboring nodes  
13 within two hops from that node. If the reservation is not made within a preset quantity of  
14 attempts as determined at step 61, processing of the reservation terminates.

15       The manner in which a network node according to the present invention processes  
16 the reservation packet and reservation information is illustrated in Figs. 7A - 7B.  
17 Specifically, a network node receives a packet at step 70. If the packet is a neighbor  
18 discovery packet containing reservation information as determined at step 72, the node  
19 extracts information (e.g., slot, architecture, source, etc.) from the reservation packet at  
20 step 74 to avoid utilization of the same slots a transmitting node has reserved. When the  
21 reservation has been confirmed as determined at step 76 (as described below), the  
22 reservation information is utilized to update a neighbor table in the node database with the  
23 final configuration and reserved slots at step 78. If further processing is to commence as  
24 determined at step 132, the node receives and processes the next packet at step 70.

25       When the received packet is a reservation packet as determined at step 80, the node  
26 extracts and stores the reservation information from the packet at step 82. If the node is a  
27 neighboring node that happens to hear the reservation request (e.g., the node is not within  
28 the routing path) as determined at step 83 and further processing is to commence as  
29 determined at step 132, the node receives and processes the next packet at step 70 as  
30 described above.

31       If the node is an intermediate node within the routing path as determined at step  
32 96, the node determines available transmission and retransmission slots based on the  
33 extracted information from the reservation packet relating to assignments or reservations

1 of the previously traversed nodes at step 84. In particular, the node retrieves the slot  
2 number the previously traversed nodes have reserved and determines the earliest available  
3 empty time slot for transmission that forms the correct time sequence with the slot  
4 assignments or reservations of the previous nodes. The determined slot should avoid  
5 collisions since the node has reservation information of neighboring nodes within two  
6 hops. Subsequently, the node reserves an earliest available empty retransmission slot that  
7 forms the correct time sequence with the retransmission slots of the previous nodes. The  
8 retransmission slots are reserved in accordance with selection of a TDMA architecture  
9 supporting retransmissions.

10 If the configuration number (e.g., TDMA architecture) received within the  
11 reservation packet can not be supported by the node as determined at step 86, the node  
12 determines the configuration number (e.g., TDMA architecture) that can be supported at  
13 step 88 and makes the required reservation. This is accomplished by altering the  
14 configuration number in the reservation packet as described below. The node further  
15 retrieves the total number of empty slots,  $S_p$ , received within the reservation packet and  
16 determines the quantity of empty slots,  $S_n$ , associated with the node. If  $S_p$  is greater than  
17  $S_n$ , then the node replaces  $S_p$  in the reservation packet with  $S_n$  at step 92. The updated  
18 packet, including the configuration number and reserved slots, is transmitted to the next  
19 node in the routing path at step 94. If further processing is to commence as determined at  
20 step 132, the node receives and processes the next packet at step 70 as described above.

21 If the node is the destination node as determined at step 96, the node determines  
22 the configuration that may be supported by each node in the routing path at step 98.  
23 Basically, the node is informed of the configuration number (e.g., TDMA architecture) of  
24 each node along the routing path via the reservation packet. The memory required for the  
25 architecture decreases with decreased complexity of the TDMA architecture as described  
26 above. Accordingly, the configuration number associated with a routing path node  
27 representing the least complex architecture (e.g., utilizing the least amount of memory) is  
28 the configuration number that can be supported by each node along the routing path. The  
29 node retrieves from the reservation packet the configuration number and the available  
30 resources for each traversed node. In accordance with this information and the total  
31 number of hops from the source node to the destination node, the destination node  
32 determines the configuration number each traversed node can support. The determined  
33 configuration number is inserted into a confirmation packet.

1       Once the configuration number is determined, the node reserves an additional  
2 acknowledgement (ACK) slot at step 100, depending upon the selected TDMA frame  
3 architecture. The node further reserves the transmission and retransmission slots for both  
4 the forward and return paths at step 102, depending upon the selected TDMA frame  
5 architecture. The node transmits a confirmation reply to the initiating or source node in  
6 the form of the confirmation packet that includes the final configuration number and the  
7 reserved slots at step 104. The reservation information is further transmitted to  
8 neighboring nodes via neighbor discovery packets at step 106. If further processing is to  
9 commence as determined at step 132, the node receives and processes the next packet at  
10 step 70 as described above.

11       If the received packet is a confirmation packet as determined at step 108, the node  
12 determines the node status (e.g., whether the node is a neighboring node of a routing path  
13 node and heard transmission of the confirmation packet) at step 110. When the node  
14 status is that of a neighboring node, the node retrieves the final configuration number and  
15 the reserved slots and updates the neighbor table within the node database accordingly at  
16 step 130. If further processing is to commence as determined at step 132, the node receives  
17 and processes the next packet at step 70 as described above.

18       When the node is the source node (e.g., initiating the reservation request) or an  
19 intermediate node along the routing path, the node determines whether the configuration  
20 within the confirmation packet is the same as the configuration number in the reservation  
21 request at step 112. If these configuration numbers are different, the configuration number  
22 is updated based upon the configuration number within the confirmation packet at step 114  
23 and the reserved slots in the forward path are updated accordingly at step 116. The node  
24 further selects slots for the return path at step 118. If the node is an intermediate node  
25 along the routing path as determined at step 120, the updated information is inserted into  
26 the confirmation packet and transmitted to the next node in the path at step 122.

27       When the node is a source node as determined at step 120, the node determines  
28 whether the configuration number (e.g., TDMA architecture) supports retransmissions at  
29 step 124. If the configuration supports retransmissions, an acknowledgement (ACK) slot  
30 is further reserved at step 126 in the manner described above. The reservation information  
31 is sent by an intermediate or source node to neighboring nodes via neighbor discovery  
32 packets at step 128. If further processing is to commence as determined at step 132, the  
33 node receives and processes the next packet at step 70 as described above.

1       Once the reservation has been accomplished, network nodes may facilitate voice  
2   communications via the reserved slots and determined frame architecture. The manner in  
3   which a network node according to the present invention facilitates voice communications  
4   is illustrated in Fig. 8. Specifically, the node determines whether to send voice  
5   information at step 140. This may be accomplished by detecting a node input mechanism  
6   (e.g., button, switch, etc.) manipulated by a user prior to entering voice signals. If the  
7   node is to transmit, the voice signals provided by a user are processed for transmission at  
8   step 142. Basically, analog voice signals from a user are entered, digitized and  
9   compressed by node audio devices 28 (e.g., a microphone, speech coder, etc.) (Fig. 1B).  
10   The number of slots available in a frame depends upon the speech coding rate and the  
11   channel data rate as described above. The encoded voice data bits are generated each  
12   frame and are transmitted in the proper reserved time slot over the voice channel to the  
13   next node or hop in the routing path at step 144.

14       If the configuration number (e.g., TDMA frame architecture) supports  
15   retransmission as determined at step 146, the node determines the presence of an  
16   acknowledgement at step 148. Basically, the transmission from the next hop is monitored  
17   by the node. If the node hears the packet transmission from the next hop, this is  
18   considered as an implicit acknowledgement and no retransmission is necessary. If the  
19   voice packet reaches the destination node, an explicit acknowledgement (ACK) is  
20   required. This ACK is transmitted in the reserved or assigned ACK slot. When no  
21   acknowledgement (e.g., implicit or explicit ACK) is received within a predetermined time  
22   interval at step 148, the node retransmits the voice packet in the reserved or assigned  
23   retransmission slot at step 150. The retransmission is preferably performed only once since  
24   retransmissions occupy several slots, thereby reducing simultaneous voice transmissions.  
25   However, the retransmissions may be performed any quantity of times.

26       If the node initiated communications (e.g., transmitted the reservation request) as  
27   determined at step 152 and a user indicated to end the communication (e.g., via a user  
28   input mechanism on the node, such as a button or switch) as determined at step 154, the  
29   node transmits a termination message along the routing path determined by the routing  
30   module at step 156.

31       When the node is to receive voice related transmissions as determined at steps 158  
32   and 160, the node determines the node status as a destination node at step 162. If the node  
33   is the destination node, the voice data is processed at step 164 via node processor 26 and

1       audio devices 28 for transfer to a user (e.g., via a node speaker, etc.) in a comprehensible  
2       manner. This may be accomplished by the node processor and/or circuitry within the audio  
3       devices. When the node is an intermediate node along the routing path as determined at  
4       step 166, the voice data is forwarded to the next node or hop in the routing path at step  
5       168.

6       If the node receives a termination message or a neighbor discovery packet with  
7       termination information as determined at step 170, the node removes the slot reservation at  
8       step 172, where the slots become available for future use. When the node is a destination  
9       node as determined at step 174, the node terminates the communication with the source  
10      node and transmits termination information to neighboring nodes via the neighbor  
11      discovery packets to remove the slot reservation at step 178. When the node is an  
12      intermediate node along the routing path as determined at step 176, the node forwards the  
13      termination message to the next node in the routing path and transmits termination  
14      information to neighboring nodes via the neighbor discovery packets to remove the slot  
15      reservation at step 180. The node processes voice communications as described above  
16      until processing ceases (e.g., shut down, etc.) as determined at step 182.

17      During voice communication, there are long silence intervals after one speaker  
18      finishes talking and waits for a response from the other speaker. These silence intervals  
19      do not contribute to the voice intelligence and removal of these intervals can conserve  
20      bandwidth for other use. Accordingly, the present invention may employ a silence detector  
21      to detect these silence intervals to prevent transmission of data bits during silence. An  
22      exemplary silence detector that may be employed by the present invention to render  
23      voicing decisions in background noise is disclosed in U.S. Patent No. 5,680,508 (Liu), the  
24      disclosure of which is incorporated herein by reference in its entirety. The silence detector  
25      may be implemented within the node processor and/or by hardware and/or software within  
26      the node to perform the silence detector functions.

27      The manner in which a node according to the present invention detects and  
28      removes silence intervals is illustrated in Fig. 9. Initially, a frame of voice data can be  
29      classified as either voice or unvoiced. A voiced frame differs from an unvoiced frame  
30      based on the voiced frame having a periodic pitch period. A silence frame is classified as  
31      unvoiced. Therefore, a frame detected to have no voicing may be either an unvoiced or  
32      silence frame. The transmitting node receives and processes voice signals from a user as  
33      described above. A silence frame is detected when an unvoiced frame lasts continuously

1 for more than N frames. The silence detector of the transmitting node tracks the frame  
2 energy,  $E_k$ , of a silence frame and determines, at step 190, a running average and variance  
3 of frame energy as follows:

4

5 
$$E_k = (1 - u)E_{k-1} + uE_f \quad (\text{Equation 2})$$

6 
$$\sigma_k = (1 - u)\sigma_{k-1} + u|E_f - E_k| \quad (\text{Equation 3})$$

7

8 where  $u$  is the weighting factor and  $E_f$  is the energy of the current frame. If a frame is  
9 detected to be unvoiced speech, the frame is not included in the running average and  
10 variance.

11 The node determines whether a frame is voiced or unvoiced speech at step 192.

12 Basically, unvoiced speech is detected if the frame is unvoiced and  $|E_f - E_k| > 2\sigma_k$ ,

13 where  $E_f$  is the energy of the current frame as described above,  $E_k$  is the running average  
14 of the silence frame energy as described above and  $\sigma_k$  is the frame energy variance as  
15 described above. If a frame is determined to be either voiced or unvoiced speech, the  
16 voice data bits or frame are transmitted along the routing path at step 194. For further  
17 examples of the operation of silence detectors, reference is made to the aforementioned  
18 U.S. patent.

19 Preferably, voice and data are transmitted on different channels with the  
20 reservation being accomplished on the data channel as described above. If both the data  
21 and voice channels are heavily utilized, there is no need to allocate voice and data traffic.  
22 However, in circumstances where one channel is lightly loaded and the other channel is  
23 heavily loaded, the present invention may allocate some of the traffic from the heavily  
24 loaded channel to the lightly loaded channel. In other words, both voice and data may  
25 occupy the same channel. The manner in which a node according to the present invention  
26 performs channel allocation is illustrated in Fig. 10. Specifically, a node determines a  
27 running average of reserved slots for the voice and data channels at step 200. Basically,  
28 the node monitors the total number of reserved slots in the voice channel and the slot  
29 utilizations in the data channel, where the data channel access scheme is not limited to be  
30 TDMA. A time running average for each channel is determined as follows:

31

32 
$$M_k = (1 - w)M_{k-1} + w * U_k \quad (\text{Equation 4})$$

1

2 where  $M_k$  represents the average of reserved time slots at time  $k$ ,  $U_k$  represents the total  
3 number of currently reserved slots and  $w$  is a weighting coefficient between 0 and 1. If  $w$   
4 is large,  $M$  can adapt faster to the most recent reserved number of slots. If  $w$  is small,  $M$   
5 can not reflect the instantaneous voice traffic variations. The node determines the average  
6 each time a new reservation packet needs to be transmitted.

7 The node further determines the percentage of reserved slots for the voice and data  
8 channels at step 202. The reserved slot percentage (e.g.,  $M_k^v$  represents the percentage for  
9 voice slot reservations and  $M_k^d$  represents the percentage for data slot utilization) is  
10 determined from the ratio of  $M_k$  and the total number of slots in a frame. If the data slot  
11 percentage is less than a lower threshold utilization percentage,  $p_1$  (e.g., the threshold  
12 indicating a light load), and the voice slot percentage is greater than an upper threshold  
13 utilization percentage,  $p_2$  (e.g., the threshold indicating a heavy load) (e.g.,  $M_k^d < p_1$  and  
14  $M_k^v > p_2$ ), as determined at step 204, the node allocates voice traffic to the data channel at  
15 step 208 (Figs. 13 – 14). If the data slot percentage is greater than the upper threshold  
16 utilization percentage,  $p_2$ , and the voice slot percentage is less than the lower threshold  
17 utilization percentage,  $p_1$ , (e.g.,  $M_k^d > p_2$  and  $M_k^v < p_1$ ), as determined at step 206, the  
18 node allocates data traffic to the voice channel at step 210 (Figs. 11 – 12). By way of  
19 example only, the lower threshold utilization percentage,  $p_1$ , may be set to 30%, while the  
20 upper threshold utilization percentage,  $p_2$ , may be set to 90%. In this case, channel  
21 allocation may occur if one channel is loaded less than 30%, while the other channel has  
22 greater than 90% utilization. However, the threshold percentages may be set to any  
23 suitable values to provide a desired channel allocation by the node.

24 Exemplary frame architectures integrating voice and data are illustrated in Figs. 11  
25 – 14. In particular, Fig. 11 illustrates a frame architecture 220 including integrated voice  
26 and data for transmission over the voice channel with support for voice retransmission. A  
27 frame architecture 230 including integrated voice and data without voice retransmission  
28 for transmission over the voice channel is illustrated in Fig. 12. The data slots preferably  
29 start at  $(p_1 + \delta)N$ , where  $p_1$  is the lower threshold utilization percentage,  $N$  is the quantity  
30 of slots in a frame and  $\delta$  is a safety factor to allow sudden voice traffic bursts. If there is a  
31 sudden voice traffic increase while the data messages are in the process of transmission,

1 the current data traffic is allowed to finish, but is barred from future use of the voice  
2 channel.

3 Figure 13 illustrates a frame architecture 240 including integrated voice and data  
4 for transmission over the data channel with support for voice retransmissions. A frame  
5 architecture 250 including integrated voice and data without voice retransmission for  
6 transmission over the data channel is illustrated in Fig. 14. The data channel frame  
7 architectures are similar in operation to those described above for the voice channel. The  
8 voice slots preferably start at  $(p_1 + \delta)N$ , where  $p_1$  is the lower threshold utilization  
9 percentage,  $N$  is the quantity of slots in a frame and  $\delta$  is a safety factor to allow sudden  
10 data traffic bursts. If there is a data voice traffic increase while the voice messages are in  
11 the process of transmission, the current voice traffic is allowed to finish, but is barred from  
12 future use of the data channel.

13 It will be appreciated that the embodiments described above and illustrated in the  
14 drawings represent only a few of the many ways of implementing a method and apparatus  
15 for dynamic voice reservation within wireless networks.

16 The communication networks employing the present invention nodes may include  
17 any quantity of those nodes or tiers. The network nodes may be arranged in any fashion  
18 into any quantity of islands each having any quantity of nodes. The backbone network  
19 may include any quantity of head nodes, while communications within an island and  
20 between neighboring head nodes of the backbone network may utilize the same or  
21 different transmission frequencies. The formation of islands and designation of head  
22 nodes may be predetermined or accomplished dynamically via any conventional or other  
23 algorithm or technique. The nodes may communicate via any suitable communications  
24 medium (e.g., wired or wireless communication devices, etc.).

25 The present invention node may include any quantity of conventional or other  
26 transmitters, receivers and/or transceivers, where each transmitter or transceiver may  
27 transmit signals at any suitable frequency and in any suitable energy form (e.g., radio  
28 signals, microwave, optical signals, etc.), and any quantity of conventional or other  
29 receivers or transceivers, where each receiver or transceiver may receive signals at any  
30 suitable frequency and in any suitable energy form (e.g., radio signals, microwave, optical  
31 signals, etc.). The present invention node may include any quantity of independent  
32 transmitting and/or receiving devices, and utilize any quantity of frequency channels of  
33 any desired frequencies to send voice and/or data. The present invention node may

1 employ any conventional access scheme or protocol to access and/or transmit information  
2 on the data channel. The present invention node may include any quantity of any  
3 conventional or other audio components (e.g., speaker, microphone, etc.) and associated  
4 circuitry or devices (e.g., coder, A/D or D/A converter, etc.) to process voice signals. The  
5 present invention node may further include any quantity of any types of input or control  
6 devices (e.g., buttons, switches, etc.) to enter voice or data and control node operation.  
7 The node may be in the form of any type of radio unit or other communications device.

8 The processor of the present invention node may be implemented by any  
9 conventional or other microprocessor, controller or circuitry to perform the functions  
10 described herein, while any quantity of processors or processing devices or circuitry may  
11 be employed within the present invention node where the processor functions may be  
12 distributed in any fashion among any quantity of hardware and/or software modules,  
13 processors or other processing devices or circuits. The software for the processor of the  
14 present invention node may be implemented in any suitable computer language, and could  
15 be developed by one of ordinary skill in the computer and/or programming arts based on  
16 the functional description contained herein and the flow charts illustrated in the drawings.  
17 Further, any references herein of software performing various functions generally refer to  
18 processors performing those functions under software control. The software and/or  
19 algorithms described above and illustrated in the flow charts may be modified in any  
20 manner that accomplishes the functions described herein. The present invention node may  
21 alternatively include any components arranged in any fashion to facilitate reservations and  
22 distribution of voice and/or data within the network in the manner described above.

23 The reservation request, confirmation, database update, neighbor discovery,  
24 termination, voice or other packets or messages may be of any size, may have any format,  
25 and may contain any desired information. The packets may be transmitted at any suitable  
26 transmission rate or have any desired interval between transmissions. The various  
27 messages or packets may include any identifier to identify the type of message or packet.  
28 The packets may be broadcasted or transmitted any quantity of times.

29 The frame architectures may be of any quantity and include any quantity of slots.  
30 The slots may be reserved or assigned in any manner, where the frame may be arranged in  
31 any fashion. The frame may include any quantity of transmission, retransmission,  
32 acknowledgement or other slots (e.g., reserved for specific purposes, for a particular  
33 application, etc.) arranged in any fashion. The frame may be structured to be compatible with

1 any network or transmission scheme (e.g., TDMA, etc.). The various slots (e.g.,  
2 transmission, retransmission, acknowledgement, etc.) may be transmitted within the same  
3 or any quantity of different frequency channels. The frame architecture may be selected in  
4 any fashion based on any conditions, predetermined and/or entered by a user in any  
5 fashion (e.g., input devices, etc.). The frame architecture may be associated with any  
6 symbol or identifier (e.g., number, alphanumeric characters, etc.).

7 The reservation, termination and other information may be embedded or  
8 piggybacked within any suitable packet (e.g., database update, neighbor discovery, etc.).  
9 Alternatively, this information may be transmitted in respective packets or messages of  
10 any quantity. The node database may be implemented by any conventional database or  
11 other storage structure (e.g., processor memory, external memory, file, data structure (e.g.,  
12 array, queue, stack, etc.), etc.) and may have any desired storage capacity to contain any  
13 desired information.

14 The database update and neighbor discovery packets may be transmitted at any  
15 desired intervals and/or in response to any desired events or conditions. The  
16 acknowledgments may be implied in any manner indicating reception of a packet by a  
17 destination node, or transmission of an acknowledgment from a receiving node may be  
18 required by a transmitting node.

19 Voice information may be received from a user and processed in any conventional  
20 or other manner for transmission. Conversely, voice information from another node may  
21 be received and processed in any conventional or other manner for conveyance to a user  
22 (e.g., via an audio device). Voice may be retransmitted any quantity of times in response  
23 to any conditions (e.g., no ACK, etc.).

24 The present invention node may employ any conventional or other silence detector.  
25 The silence detector may be implemented within the node processor or via hardware  
26 and/or software modules or circuitry disposed within the node. The node may include any  
27 quantity of channels and allocate voice and/or data to those channels in any manner. The  
28 threshold utilization percentages may be set to any desired values to control allocation of  
29 voice and data to the data channels. Voice and data may be integrated into a channel  
30 frame in any fashion. The frames may include any quantity of slots (e.g., any quantity for  
31 data, voice, retransmissions, etc.) arranged in any fashion. The additional allocated  
32 information (e.g., voice for the data channel and data for the voice channel) may start at

1 any desired slot position, where a safety or buffer factor may be utilized and set to any  
2 desired quantity of slots.

3 It is to be understood that the present invention is not limited to the applications or  
4 networks described herein, but may be utilized for various communication applications or  
5 networks, especially those transmitting voice and/or including wireless Ad Hoc radio  
6 networks.

7 From the foregoing description, it will be appreciated that the invention makes  
8 available a novel method and apparatus for dynamic voice reservation within wireless  
9 networks, wherein a multi-hop wireless Ad-Hoc network employs voice reservation with  
10 dynamic selection of frame architectures depending on voice mode operation (e.g.,  
11 simplex/duplex) and associated retransmission/acknowledgement mechanisms.

12 Having described preferred embodiments of a new and improved method and  
13 apparatus for dynamic voice reservation within wireless networks, it is believed that other  
14 modifications, variations and changes will be suggested to those skilled in the art in view  
15 of the teachings set forth herein. It is therefore to be understood that all such variations,  
16 modifications and changes are believed to fall within the scope of the present invention as  
17 defined by the appended claims.